ISSN: 2754-4753

Journal of Physics & Optics Sciences

SCIENTIFIC Research and Community

Review Article

Open Access

Low-Energy Nuclear Transmutations and a Process that Ensures the Conservation of Angular Momentum

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ABSTRACT

The aim of the article is to prove that Low-Energy Nuclear Transmutations may be performed by a process that emerges due to change in spin orientation of virtual photons created by quantum objects taking part in low-energy nuclear transmutations. According to Feynman's theory, virtual photon has the properties of spin vortex (precessing spin and electric dipole moment) and is produced in physical vacuum characterized by inner angular momentum. Interaction of virtual photons by means of interaction of their electric dipoles can result in inversion of one of the electric dipole moments and, consequently, in inversion of spin related to it.

The reorientation of spin of virtual photon means the reorientation of angular momentum in physical vacuum and, in accordance with the law of conservation of angular momentum, the processes compensating the changes in angular momentum emerge. The moment related to the inertial properties of the physical vacuum may be a characteristic of this process. This moment while acting on electric dipole moments of virtual photons of quantum objects can cause, firstly, the energy generation, and, secondly, the reorientation of these electric dipole moments in physical vacuum. The changes in orientations of electric dipole moments of virtual photons act on characteristics of quantum objects creating these virtual photons and in such a way on the structure of chemical elements containing these quantum objects. In such a way the transmutations of chemical elements can take place.

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Received: October 15, 2025; **Accepted:** October 21, 2025; **Published:** November 10, 2025

Keywords: Virtual Photon, Electric Dipole Moment, Law of Angular Momentum Conservation, Inversion of Spin, Low-Energy Nuclear Transmutation

Introduction

The processes that determine the execution of low-energy nuclear reactions are analyzed in this work. Such physical processes are:

1) the creation of virtual photons by quantum objects which are features in electric and/or magnetic fields [1-2];

2) the inversion of electric dipole moment of one of the virtual photons and simultaneously inversion of its spin; the inversions are accompanied by generation of energy [3];

3) the process compensating the change in angular momentum; the latter is a result of spin inversion.

The moment related to the inertial properties of the physical vacuum is the main characteristic of process that ensures the conservation of angular momentum. (This is the process similar to that which defines Newton's first law (law of inertia) [4]). This moment while acting on electric dipole moments of virtual photons of quantum objects can cause: firstly, the reorientation of these dipole moments in physical vacuum and, secondly, the energy generation. The changes in orientations of electric dipole moments of virtual photons act on characteristics of quantum objects creating these virtual photons and in such a way on the structure of chemical elements containing these quantum objects. Thus, the transmutations of chemical elements can take place.

In the next sections, the above physical processes determining the execution of low-energy nuclear reactions will be considered in detail.

1. Creation of Virtual Photons by Quantum Object

1.2. The properties of virtual photon

In 1965, R. F. Feynman won the Nobel Prize for his hypothesis about creation by quantum objects, that are features in electric and magnetic fields, of objects having properties of photon [1]: spin $\mathbf{S}_v$ and electric dipole moment $\mathbf{d}_v$ (as follows from experiments with so-called Transverse Optical Force, photon has an electric dipole moment [5]):

$$\mathbf{d}_v \uparrow\uparrow \mathbf{S}_v . \quad (1)$$

Feynman called the object proposed by him "virtual photon".

Some properties of virtual photon are similar to properties of spin vortex [2]. Similar to properties of spin vortex, spin $\mathbf{S}_v$ performs precession motion with frequency $\boldsymbol{\omega}_v$ defined according to property of gyroscopes [6] as:

$$\mathbf{M}_v = \boldsymbol{\omega}_v \times \mathbf{S}_v , \quad (2)$$

where $\mathbf{M}_v$ is a moment causing precession; and:

$$\boldsymbol{\omega}_v \uparrow\uparrow \mathbf{S}_q , \quad (3)$$

where $\mathbf{S}_q$ is a spin of quantum object that creates virtual photon.

As the charge of quantum object acts on electric dipole moment $\mathbf{d}_v$ of virtual photon created by this quantum object and following it, the following is valid with taking into account Eqs (1) and (2):

$$\boldsymbol{\omega}_v \uparrow\uparrow \eta \mathbf{u} , \quad (4)$$

$$\eta = \begin{cases} 1, & \textit{for positively charged of quantum objects} \\ -1, & \textit{for negatively charged of quantum objects} \end{cases} , \quad (5)$$

where $\mathbf{u}$ is velocity of quantum object.

Figure 1 contains schemas of virtual photons created by both negatively and positively charged quantum objects with taking into account that the size of virtual photon is equal to wavelength $\lambda\!\!\!^{-}_q$ of quantum object creating the virtual photon [1].

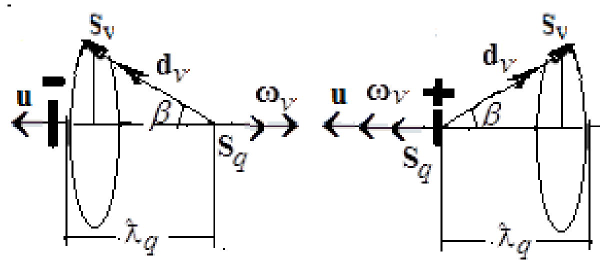

Figure 1. Schemas of virtual photons created by both negatively (variant (a)) and positively (variant (b)) charged quantum objects. $\mathbf{d}_v$ are electric dipole moments; $\boldsymbol{\omega}_v$ are frequencies of precession of spins $\mathbf{S}_v$; β are angles of deflection; $\mathbf{u}$ and $\mathbf{S}_q$ are velocities and spins of quantum objects; $\lambda\!\!\!^{-}_q$ are sizes of virtual photons.

The angle of deflection β is determined by speed u of quantum object and by speed of light c [2]:

$$\sin\beta = u / c . \quad (6)$$

1.2. Definition of expressions for electric dipole moments of virtual photons created by electron and proton, respectively $\mathbf{d}_{ve}$ and $\mathbf{d}_{vp}$

Based on the results of experiments conducted by Kaufmann [7] on the deflection of beta-rays emitted by radium, which showed that the mass of electron m_e is purely of an electromagnetic nature, we assume that the same is valid for the virtual particle (with mass $m_v/2$ and charge q_v) that, according to hypothesis of Feynman, makes up the virtual photon with mass m_v: that is, the following holds: $e/m_e = 2q_v/m_v$ (e is the electric charge of electron). From the latter expression we obtain the expression for q_v:

$$q_v = em_v / (2m_e) . \quad (7)$$

As, according to Feynman's hypothesis, the properties of virtual photon are similar to the properties of photon, the mass of virtual photon will be defined similar to kinetic mass of photon $m_{ph}: m_{ph} = U_{ph}/c^2$, where U_{ph} is photon energy, c is the speed of light. Consequently, the mass of virtual photon m_v may be defined as:

$$m_v = U_q / c^2, \quad (8)$$

where U_q is the energy of quantum object creating the virtual photon.

In general, electric dipole moment d_v of virtual photon is defined by the electric charge q_v of virtual particle that constitutes virtual photon (according to Feynman hypothesis [1]) and size of virtual photon $\lambda\!\!\!^{-}_q$:

$$\mathbf{d}_v = q_v \cdot \lambda\!\!\!^{-}_q . \quad (9)$$

Note. Essentially, the formula (9) unites classical mechanics (electric dipole moment and electric charge) with quantum concept (wavelength of wave function of quantum object defined by its moment p_q [8]):

$$\lambda\!\!\!^{-}_q = \hbar / p_q . \quad (10)$$

Solving together Eqs (7)-(10) and using the formula for Bohr magneton $\mu_B = e\hbar/(2m_e c)$, we obtain the following expression for electric dipole moment d_v of virtual photon created by quantum object:

$$d_v = \mu_B U_q / (c p_q). \quad (11)$$

If the energy of the quantum object (with mass m_q and velocity **u**) is equal to its kinetic energy ($U_q = m_q u^2/2$) and taking into account $p_q = m_q u$, the equation (11) can be rewritten in the form:

$$d_v = \mu_B u / (2c). \quad (12)$$

The equation (12) can be extended to electric dipole moment of electron d_{ve} if speed u is equal to the speed of electron u_e:

$$d_{ve} = \mu_B u_e / (2c). \quad (13)$$

The equation (12) can be extended as well to electric dipole moment of proton d_{vp} if the speed u is equal to the speed of proton u_p and the magneton of Bohr $\mu_B = e\hbar/(2m_e c)$ is replaced by nuclear magneton μ_N:

$$d_{vp} = \mu_N u_p / (2c). \quad (14)$$

1.3. Energy characteristic of virtual photon

The interaction of virtual photons is characterized by energy W_v, moment $\mathbf{M}_v$, force $\mathbf{F}_v$. These characteristics in the CGS system can be determined by the following expressions [9]:

$$W_v = \left((\mathbf{d}_{v1}\mathbf{d}_{v2}) r^2 - 3(\mathbf{d}_{v1}\mathbf{r})(\mathbf{d}_{v2}\mathbf{r}) \right) / r^5, \quad (15)$$

$$\mathbf{M}_v = \left[\mathbf{d}_{v2}, \left(\left(3\mathbf{r}(\mathbf{d}_{v1}\mathbf{r}) - \mathbf{d}_{v1} r^2 \right) / r^5 \right) \right], \quad (16)$$

where r is the distance (**r** is vector of distance) between virtual photon.

If mutual orientation of electric dipole moments of virtual photons is parallel or antiparallel, force $\mathbf{F}_v$ between them is determined as:

$$\mathbf{F}_v = \begin{cases} k\mathbf{d}_{v1}\mathbf{d}_{v2}/r^4 - \textit{attractive if } \mathbf{d}_{v1}\uparrow\downarrow\mathbf{d}_{v2} (k{=}3) \textit{ or } \mathbf{d}_{v1}\rightarrow\rightarrow\mathbf{d}_{v2} (k{=}6). \\ k\mathbf{d}_{v1}\mathbf{d}_{v2}/r^4 - \textit{repulsive if } \mathbf{d}_{v1}\uparrow\uparrow\mathbf{d}_{v2} (k{=}{-}3) \textit{ or } \mathbf{d}_{v1}\leftarrow\rightarrow\mathbf{d}_{v2} (k{=}{-}6). \end{cases} \quad (17)$$

Equations (15)-(17) are valid if distance r between interacting virtual photons is much greater than their size $\lambda\!\!\!^{-}_q$, that is:

$$\lambda\!\!\!^{-}_q << r. \quad (18)$$

Let us analyze energy characteristics of virtual particle in more detail using as an example the energy property of molecule of hydrogen, see Figure 2.

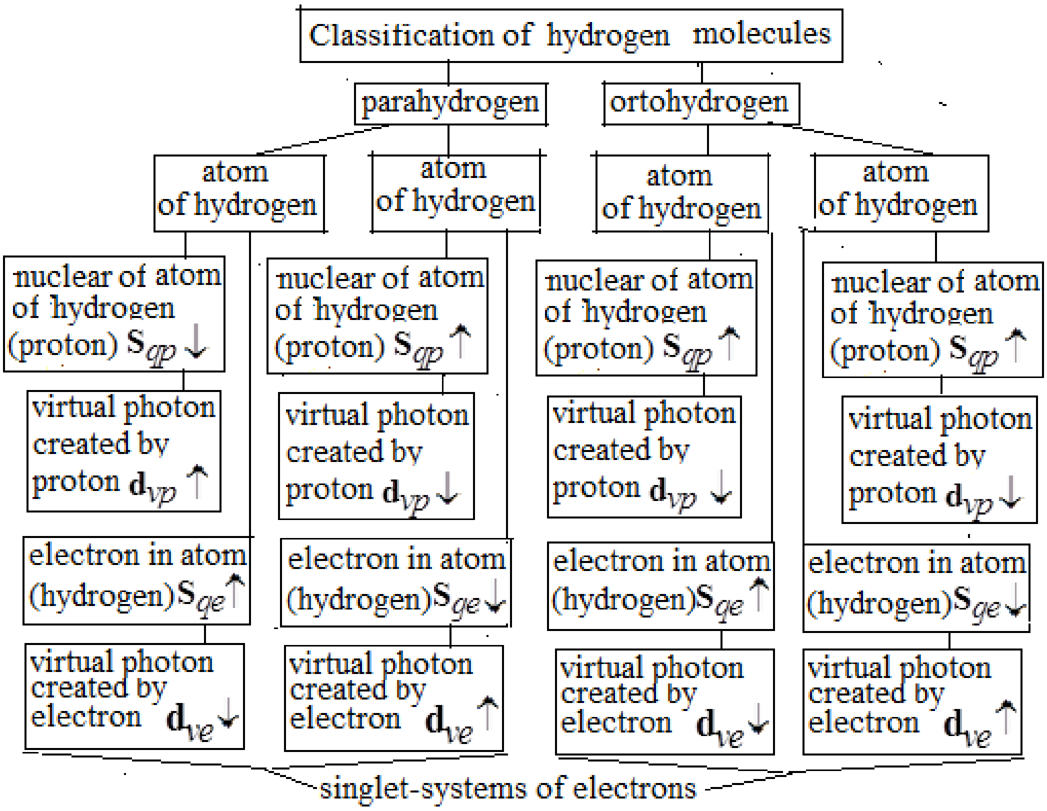

Figure 2. The schematic image of hydrogen structure. The hydrogen consists of molecules of two types: parahydrogen and ortohydrogen. $\mathbf{S}_{qp}$ - spins of protons (nuclei of atoms of hydrogen molecules); $\mathbf{d}_{vp}$ - electric dipole moments of virtual photons created by protons; $\mathbf{S}_{qe}$ - spins of electrons; $\mathbf{d}_{ve}$ - electric dipole moments of virtual photons created by electrons.

Let us consider the features [10] of the diagram in Figure 2.

1) There exist two spin forms of molecular hydrogen: parahydrogen (p-H_2) containing two protons with the opposite orientations of their spins; and ortohydrogen (o-H_2) containing two protons with the same spin orientation. According to Eqs (1)-(3), the spin of proton $\mathbf{S}_{qp}$ is related to electric dipole moment $\mathbf{d}_{vp}$ of virtual photon created by proton by condition:

$$\mathbf{d}_{vp} \uparrow\downarrow \mathbf{S}_{qp}. \quad (19)$$

2) Protons that make up the molecule of parahydrogen (have antiparallel spins $\mathbf{S}_{qp}$) create virtual photons that, according to Eq. (19), have oppositely oriented electric dipole moments $\mathbf{d}_{vp}$. The schematic representation of virtual photons created by nuclei of parahydrogen (protons) with antiparallel spins $\mathbf{S}_{qp}$ is shown in Figure 3. According to definition of parahydrogen and Eqs. (17) and (19), attractive force $\mathbf{F}_{vp+}$ acts between virtual photons created by protons of parahydrogen and consequently between these protons. According to Eq. (17) and

(14), if condition (18) is fulfilled, $\mathbf{F}_{vp+}$ is determined as $\mathbf{F}_{vp+} = 3\left(\mu_N u_p / \left(2cr_{vp}^2\right)\right)^2$. With taking into account the data of parahydrogen [3, 11]:

u_p = 1.85 10^5cm/s, r_{vp} =0.74 10^{-8}cm.

$$\mathbf{F}_{vp+} = 3\ 10^{-25}\text{dyne}. \qquad (20)$$

Let us check in this case the feasibility of condition (18): $\lambda\!\!\!^{-}_q = \hbar / \left(m_p \cdot u_p\right) = 0.32\ 10^{-8}$cm , where m_p is mass of proton. Thus $\lambda\!\!\!^{-}_q < r_{vp}$ =0.74 10^{-8}cm. Consequently, the condition (18) is fulfilled approximately.

Note to Eq.20. As follows from Fig.3, the expression (20) must contain multiplier $\cos^2\beta$*, where, according to Eq. (6),* $\cos^2\beta = 1 - \sin^2(u/c)$*. Since in the considered case* $\cos^2\beta = 1 - 10^{-10} \approx 1$, *we can ignore this multiplier.*

According to Eq. (15), the interaction energy in this case, W_{vp+}, will be negative:

$$W_{vp+} < 0. \qquad (21)$$

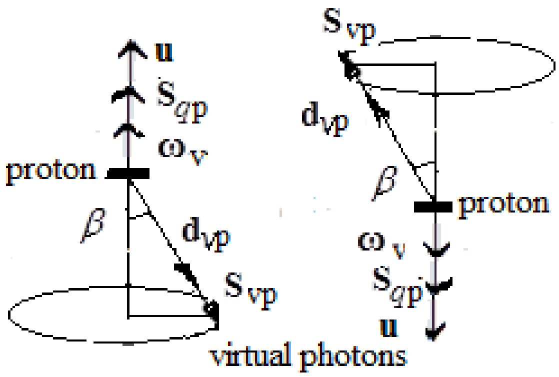

Figure 3. The schematic image of virtual photons created by nuclei (protons) that constitute parahydrogen. $\mathbf{S}_{qp}$ are spins of protons constituting parahydrogen. The characteristics of virtual photons: $\mathbf{S}_{vp}$ are spins; $\mathbf{d}_{vp}$ are electric dipole moments; $\boldsymbol{\omega}_v$ are frequencies of precession; β are angles of the deflection; **u** are velocities.

3) Protons constituting ortohydrogen (have parallel spins $\mathbf{S}_{qp}$) create virtual photons that, according to Eq. (19), have uniformly oriented electric dipole moments $\mathbf{d}_{vp}$. The schematic image of virtual photons created by nuclei (protons) that constitute ortohydrogen is shown in Figure 4.

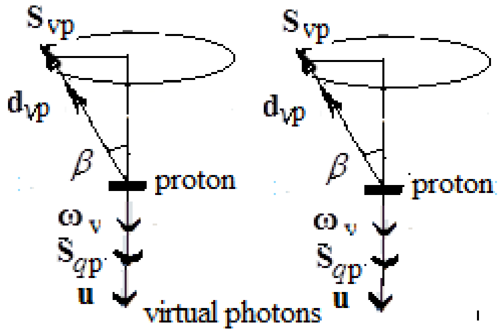

Figure 4. The schematic image of virtual photons created by protons with parallel spins ($\mathbf{S}_{qp}$) constituting ortohydrogen. Characteristics of the virtual photons: $\mathbf{S}_{vp}$ are spins; $\mathbf{d}_{vp}$ are electric dipole moments; $\boldsymbol{\omega}_v$ are frequencies of precession; β are angles of deflection; **u** are velocities.

According to definition of ortohydrogen and Eqs. (17) and (18), repulsive force $\mathbf{F}_{vp-}$ acts between virtual photons created by protons of ortohydrogen and consequently between these protons. Force $\mathbf{F}_{vp-}$ is determined by the same formula as $\mathbf{F}_{vp+}$ (Eq. (14)); and let us assume as well that force $\mathbf{F}_{vp-}$ has the same order of magnitude as $\mathbf{F}_{vp+}$(Eq. (20)):

$$\mathbf{F}_{vp-} = \mathbf{F}_{vp+} = 3\ 10^{-25}\text{dyne}. \qquad (22)$$

Note to Eq.(20) is valid in this case as well.

According to Eq. (15), the interaction energy of virtual photons created by protons of ortohydrogen W_{vp-} will be positive:

$$W_{vp-} > 0. \qquad (23)$$

4) Every atom of hydrogen contains an electron with spin $\mathbf{S}_{qe}$. According to Eqs (1)-(3), the spin of electron is related to electric dipole moment

$\mathbf{d}_{ve}$ of virtual photon created by electron by condition:

$$\mathbf{d}_{ve} \uparrow\downarrow \mathbf{S}_{qe}. \quad (24)$$

Let us consider the variant where electrons created by atoms of the same molecule (parahydrogen or ortohydrogen) have opposite orientations of their spins $\mathbf{S}_{ve}$ (Fig. 5), that is they are in the singlet state.

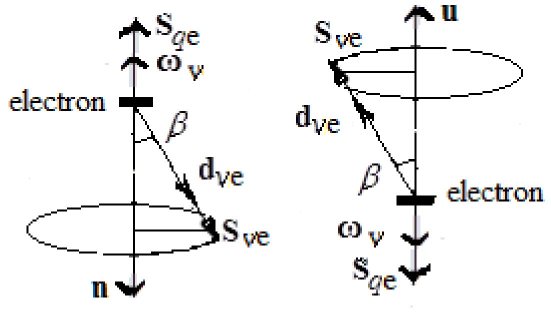

Figure 5. The schematic image of virtual photons created by electrons with antiparallel spins ($\mathbf{S}_{qe}$). Characteristics of the virtual photons: $\mathbf{d}_{ve}$ are electric dipole moments; $\boldsymbol{\omega}_v$ are frequencies of precession of spins $\mathbf{S}_{ve}$; β are angles of deflection; **u** are velocities.

According to Eqs. (17) and (24), attractive force $\mathbf{F}_{ve+}$ acts between virtual photons created by electrons and consequently between these electrons. According to Eqs (13) and (17) (if condition (18) is fulfilled), $\mathbf{F}_{ve+}$ is determined as: $\mathbf{F}_{ve+} = 3\left(\mu_B u_e / \left(2cr_{ve}^2\right)\right)^2$. With taking into account electron data: u_e= 2.2 10^8cm/s, r_{ve}=0.37 10^{-8}cm [3, 11], we obtain:

$$\mathbf{F}_{ve+} = 3\cdot 10^{-11}\,\text{dyne} \quad (25)$$

Let us check in this case the feasibility of the condition (18): $\lambda_q = \hbar/\left(m_e \cdot u_e\right) = 0.5\ 10^{-8}$cm.

Thus $\lambda_q > r_{vp}$=0.37 10^{-8}cm. Consequently, the condition (18) is hardly fulfilled in this case.

We assume that Note to Eq.(20) is valid in this case as well.

According to Eq. (15), the interaction energy in this case W_{vp+} will be negative:

$$W_{vp+} < 0. \quad (26)$$

From comparison of forces $\mathbf{F}_{vp-}$ (Eq. (22)) and $\mathbf{F}_{ve+}$ (Eq. (25)) it follows that repulsive force $\mathbf{F}_{vp-}$ between virtual photons created by protons of ortohydrogen is less than attractive force $\mathbf{F}_{ve+}$ acting between virtual photons created by electrons in the singlet state. It follows also from comparison (in parahydrogen) of force $\mathbf{F}_{vp+}$ (Eq. (20)) and repulsive force $\mathbf{F}_{ve-}$ which could act between virtual photons created by electrons in the triplet state (Eqs (13) and (17)) that attractive force $\mathbf{F}_{vp+}$ between virtual photons created by protons of parahydrogen is less than repulsive force $\mathbf{F}_{ve-}$ which could act between virtual photons created by electrons in the triplet state. Thus, the following conclusion can be drawn: the absolute value of force (denote it $\mathbf{F}_{vp}$) acting between virtual photons created by protons in the above considered cases is less than the absolute value of force (denote it $\mathbf{F}_{ve}$) acting between virtual photons created by electrons in the above considered cases, that is:

$$\mathbf{F}_{vp} < \mathbf{F}_{ve}. \quad (27)$$

It follows from inequality (27) that a hydrogen molecule (both parahydrogen and ortohydrogen) is formed if electrons of this molecule are in the singlet state that is with antiparallel spins (an attractive force acts between them) and is not formed if electrons of this molecule are in the triplet state, that is with parallel spins (a repulsive force acts between them in this case). This conclusion is in accordance with experimental data.

2. The Inversion of Electric Dipole Moment and Spin of Virtual Photon Created by Nucleus of Ortohydrogen

As follows from Figure 2, the four of pairs of virtual photons exist in a hydrogen molecule:

1) a pair of virtual photons created by the nuclei (protons) of parahydrogen (Figure 3);

2) a pair of virtual photons created by the nuclei (protons) of ortohydrogen (Figure 4);

3) a pair of virtual photons created by the electrons related to nuclei (protons) of ortohydrogen (Figure 5);

4) a pair of virtual photons created by the electrons related to nuclei (protons) of parahydrogen (Figure 5).

According to Eq. (16), in every pair the moment $\mathbf{M}_v$ can cause the inversion of electric dipole moment of one of the virtual photons of the pair; the inversion is accompanied by a change in the energy of these virtual photons. According to Eqs (21), (23) and (26), the inversion is produced with energy emission only in ortohydrogen pair (Figure 4). In this case the inversion of electric dipole moment $\mathbf{d}_{vp}$ of virtual photon created by proton constituting one of the atoms of a hydrogen molecule occurs; according to Eqs (23) and (15)), the value of energy changes from positive to negative. According to Eqs. (1)-(3), the inversion of electric dipole moment $\mathbf{d}_{vp}$ of virtual photon means the inversion of both virtual photon spin $\mathbf{S}_{vp}$ and spin $\mathbf{S}_{qp}$ of proton creating this virtual photon. This process is observed in experiments [3] and is called "orto-para conversion" (ortohydrogen transforms into parahydrogen).

3. The Physical Processes Generated by Inversion of Virtual Photon Spin

The schema illustrating inversion of spin $\mathbf{S}_{vp}$, spin $\mathbf{S}_{qp}$ and electric dipole moment $\mathbf{d}_{vp}$ of virtual photon created by nucleus of ortohydrogen (by proton) is shown in Figure 6.

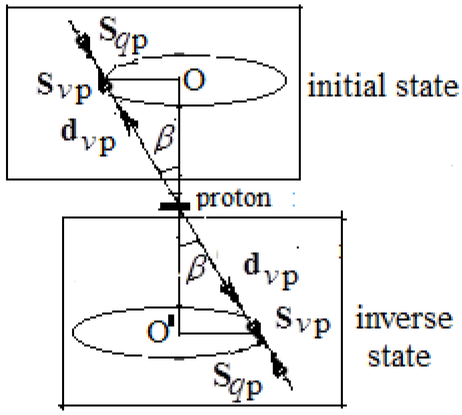

Figure 6. The schema illustrating the process of inversion of spin $\mathbf{S}_{vp}$ and electric dipole moment $\mathbf{d}_{vp}$ of virtual photon created by nucleus (proton) of ortohydrogen and also inversion of spin of nucleus (proton) $\mathbf{S}_{qp}$ in ortohydrogen.

As a result of inversion of virtual photon spin $\mathbf{S}_{vp}$, the projection of this spin on axis OO' changes by an amount $2\mathbf{S}_{vp}\cos\beta$; the angle of rotation of spin equals π. Due to action of the law of conservation of angular momentum, a process that ensures the conservation occurs in physical vacuum [4]. The following theory exists: the time derivative of the angular momentum of the system relative to chosen area of physical vacuum equals the vector sum of moments ($\mathbf{M}_{in}$) of external forces in this area. In general, the following formula is valid:

$$\mathbf{M}_{in} = \gamma \partial \mathbf{S}_v / \partial t, \tag{28}$$

where γ is a proportionality coefficient.

The moment $\mathbf{M}_{in}$ can act on spins of virtual photons created by surrounding quantum objects; thus, a chain reaction of spin inversions may occur. The action of moment $\mathbf{M}_{in}$ can result in the following processes.

1) The generation of energy at inversion of spins of virtual photons created, for example, by protons of ortohydrogen.

2) The possibility of change in the elemental composition of the surrounding objects. For example,

the inversion of electric dipole moment (spin as well) of one of the two virtual photons created by electrons can transform the states of these electrons: from triplet into singlet and back.

3) The action of moment $\mathbf{M}_{in}$ can lead to change in energy levels of atoms. Let us consider the case where atomic electrons are in *p*-state, that is electric dipole moments (respectively $\mathbf{d}_1$ and $\mathbf{d}_2$) of virtual photons created by these electrons are oriented as $\mathbf{d}_1 \rightarrow\rightarrow \mathbf{d}_2$ [9, 10]. If moment $\mathbf{M}_{in}$ changes the orientation of $\mathbf{d}_1$ and $\mathbf{d}_2$ by $\pi/2$, the following takes place: $\mathbf{d}_1 \uparrow\uparrow \mathbf{d}_2$. The next variants are possible: (1) the emerging triplet state of considered electrons is transformed into singlet state $\mathbf{d}_1 \uparrow\downarrow \mathbf{d}_2$ with emission of energy; (2) the repulsive force arises between electrons in triplet state and they can leave atom.

4) According to (1)-(3), uniform spin inversion of virtual photons can lead to magnetization of quantum objects creating these virtual photons. This theoretical conclusion is confirmed by experimental data [12].

5) In accordance with determination $\mathbf{M}_{in}$ (Eq. (28)) the effectivity of influence $\mathbf{M}_{in}$ increased at using catalysts increasing the velocity of process [3]. It is in accordance with the successful use of Ni and Cu in low-energy nuclear reactions [3, 12].

Note. The fundamental role of law of conservation of angular momentum in low-energy nuclear reactions does not exclude the possibility of description of some characteristics of nuclear transmutation in low-temperature plasma from the viewpoint of other laws of conservation: laws of conservation of energy, momentum, charges (lepton, baryon, electric [13]).

4. Discussion

Every virtual photon has precessing spin $\mathbf{S}_v$ which is characterized by frequency of precession $\boldsymbol{\omega}_v$, angle of precession α and angle of deflection β (Figure 7).

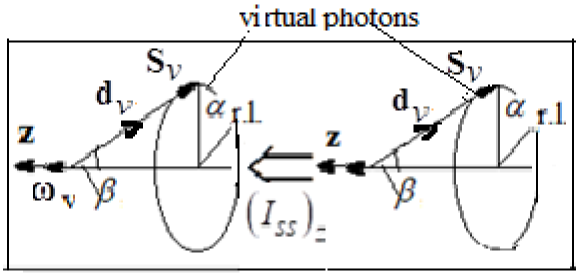

Figure 7. Schematic image of characteristics of virtual photons. $\boldsymbol{\omega}_v$ are frequencies of precession of spins $\mathbf{S}_v$; β are angles of deflection; α are angles of precession; r.l. are reference lines; z is axis; $(\mathbf{I}_{ss})_z$ are spin supercurrent; $\mathbf{d}_v$ are electric dipole moments.

Spin supercurrent $(\mathbf{I}_{ss})_z$ can emerge between the virtual photons and its value is determined as:

$$(I_{ss})_z = -g_1 \partial\alpha / \partial z - g_2 \partial\beta / \partial z, \quad (29)$$

where g_1 and g_2 are coefficients depending on β [14-16]. Thus, spin supercurrent equalizes orientations of spins, that is it performs a function similar to that of a moment $\mathbf{M}_{in}$.

It is shown in [17] that some properties of so-called "strange radiation" characterizing the Low-Energy Nuclear Transmutations are explained by action of spin supercurrent.

1) A spin supercurrent does not arise between quantum objects creating virtual photons having total zero spin. The most probable is the emergence of a spin supercurrent in substances that have "free" quantum objects, such as in metals containing "free" electrons.

2) The spin supercurrent is not an electric and is not a magnetic process.

3) Spin supercurrent is capable to magnetize the substance.

4) By definition spin supercurrent transforms angles of precession and deflection, consequently, the emerging tracks on the surface of various materials may have a vortex form [18].

Figure 8. The tracks emerging on the surface of various materials and having vortex form.

5) If spin supercurrent causes the contraction of the medium where it spreads and the speed of spin supercurrent is greater than the speed of spreading this contraction, then the action of spin supercurrents can result in appearance of periodically repeating jumps in density.

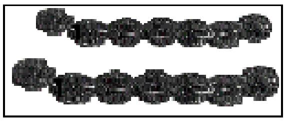

Figure 9. The possible structure of twin-tracks in experiments with low-energy nuclear reactions.

6) The "strange radiation" can exist after the end of nuclear reaction. That is, afteraction takes place. It may be related to gyroscopic properties of spins.

7) Some effects related to the nuclear reaction can occur not only in the nuclear reactor but in the region surrounding the reactor. These phenomena can exist due to long-range character of spin supercurrent.

Conclusion

The following physical processes can determine Low-Energy Nuclear Transmutations.

1) The creation by quantum objects (which are features in electric and magnetic fields) of virtual photons having spin and electric dipole moment.

2) Inversion of one of the parallel oriented electric dipole moments of virtual photons with generation of energy. (For example, transformation of hydrogen molecule from ortohydrogen form into parahydrogen form.) Simultaneously with inversion of electric dipole moment created by virtual photon, the inversion of spin of this virtual photon also takes place.

Note. These processes may exist as well without hydrogen atoms.

3) The inversion of spin of the virtual photon means the change in orientation of angular momentum in physical vacuum. In this case, due to existence of law of conservation of angular momentum, the process of compensation of this change occurs. Such a process can be a moment $\mathbf{M}_{in}$ related to the inertial properties of the physical vacuum. $\mathbf{M}_{in}$ can act on the orientation of electric dipole moments of virtual photons created by quantum objects that make up the experimental setup, and by such way influence the structure of molecules containing those quantum objects. That is, the action of moment $\mathbf{M}_{in}$ can lead to the transmutation of chemical elements.

Note. The considered process can begin not only from orto-para conversion of hydrogen atom. It may exist without a hydrogen atom at all.

4) One particle cannot be a result of nuclear reaction, otherwise it is impossible to comply with the law of conservation of angular momentum [13].

5) The nuclear reactions are a result of interaction of a large number of particles and consequently they must be investigated by laws of thermodynamics. This conclusion is consistent with many theoretical works [19, 20].

References

1. Feynman R (1949) Space-time approach to quantum electrodynamics. Phys Rev 76: 769-789.
2. Boldyreva LB (1921) A Theory of Spin Vorticies in a Physical Vacuum Consisting of Quantum Oscillators. Cambridge Scholars Publishing. https://www.cambridgescholars.com/product/978-1-5275-6455-8.
3. Matsumoto M, Espenson JH (2005) Kinetics of the Interconversion of Parahydrogen and Orthohydrogen Catalyzed by Paramagnetic Complex Ions. Journal of the American Chemical Society 127: 11447-11453.
4. Boldyreva LB (2024) The First Law of Newton. Formula and Consequences. Changes in Weight and Forward Motion of Rotating Bodies. Journal of Physics & Optics Sciences 6: 1-10.

5. Li M, Pernice WHP, Xiong C, Baehr-JT, Hochberg M, et al. (2008) Harnessing optical forces in integrated photonic circuits. Nature 456: 480-484.
6. Sedov LI (1971-1972) A Course in Continuum Mechanics, v. 1-4. Groningen: Wolters-Noordhoff.
7. Kaufmann W (1902) Die elektromagnetische Masse des Elektrons. Phys Z 4: 54-56.
8. Wichmann E (1971) Quantum Physics. Berkeley physics course, v. IV, New York: McGraw-Hill Book company.
9. Purcell E (1965) Electricity and Magnetism. Berkeley physics course, v. 2. New York: McGraw-Hill Book company.
10. Boldyreva LB (2025) A Description of the Properties of Electrons in an Atom without Mathematical Tools of Wave-Particle Dualism. Journal of Physics & Optics Sciences 7: 1-9.
11. Richardson OW (1934). Molecular hydrogen and its spectrum. Yale University, New Haven, Connecticut. 343 pp.
12. Parkhomov AG, Zabavin SN, Temirbulatov TR, Alabin KA, Andreev SN et al. (2017) Nickel-hydrogen reactors: heat release, isotopic and elemental composition fuel. RENSIT. 9: 74-93.
13. Filippov DV, Urutskoev LI (2004) On the possibility of nuclear transformation in low-temperature plasma from the viewpoint of conservation laws. Annales de la Fondation Louis de Broglie 29: 1187-1205.
14. Borovic-Romanov AS, Bunkov YM, Dmitriev VV, Mukharskii YM, Sergatskov DA (1989) Investigation of Spin Supercurrents in ^{3}He-*B*. Phys Rev Lett 62: 1631-1634.
15. Bunkov YM (2009) Spin Superfluidity and Coherent Spin Precession. Journal of Physics: Condensed Matter 21: 164201 (6 pp).
16. Dmitriev VV, Fomin IA (2009) Homogeneously precessing domain in ^{3}He-B: formation and properties. Journal of Physics: Condensed Matter 21: 164202 (9 pp).
17. Boldyreva LB (2021) Spin Supercurrent as a “Strange” Radiation in Low-Energy Nuclear Reactions. International Journal of Physics 9: 280-285.
18. Zhigalov VA, Parkhomov AG, Zabavin SN, Sobolev AG, Timerbulatov TR (2018) Track statistics strange radiation from operating reactors LENR. https://e-catworld.com/wp-ontent/uploads/2018/10/Strange-Radiation.pdf.
19. Baranov DS, Zatelepin VN (2019) Long-range operation in heat exchange processes. Academy of Trinitarism, M., El. № 77-6567, publ.25816, 22.10.2019.
20. Parkhomov AG (2023) Thermodynamic approach to the explanation of cold nuclear transmutations. Proceedings of the 27-th Russian conference of cold nuclear transmutation of chemical elements and ball lightning, Moscow: 181-186.